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A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Master of Science

BY

FRANK A. GLENN, CAPTAIN, USAF, BSC

Oklahoma City, Oklahoma

1998

THE TEST-RETEST RELIABILITY OF THE UNITED STATES AIR FORCE SUBMAXIMAL BICYCLE ERGOMETRY AEROBIC FITNESS TEST

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CHAPTER I

INTRODUCTION

The ability to perform endurance work is dependent on aerobic metabolism. Maximal oxygen consumption (VO_{2max}) defines aerobic capacity and quantifies an individual's capability for aerobic resynthesis of adenosine triphosphate (6,51). VO_{2max} is the primary indicator of aerobic fitness, cardiovascular health, and endurance performance (2,22,39,51,93).

When assessing aerobic capacity, a type of exercise must be chosen which involves a large group of muscles and be of sufficient intensity and duration to cause an adjustment in the cardio-respiratory system to the level of exercise (7,74,91). The typical exercise modes include treadmill running and walking, endurance runs and walks for time or distance, stationary cycling, arm cranking, bench stepping, and swimming (10,66,74). To determine aerobic capacity, a maximal test (direct measurement) or a submaximal test (estimation or prediction) is used to obtain a VO_{2max} value (2,31,91).

The traditionally accepted criterion measurement of aerobic capacity or "gold" standard is directly measured VO_{2max} by means of a maximal test (2,5,6,51,57,70). Measurement of VO_{2max} is a laboratory procedure involving maximal cycle or treadmill exercise and direct analysis of expired respiratory gases. It usually takes one hour to administer, requires expensive laboratory equipment, and a technical staff of at least two (2,39,40,65). Direct measurement is generally reserved for research or diagnostic purposes and is associated with a certain medical risk in unscreened, untrained, and older populations (2,31,66). Maximal cycle ergometry or treadmill laboratory tests are highly

reproducible (r = 0.95-0.98) with a standard error of the estimate (SEE) of 1-3 ml/kg/min (2,6,51,55,56). Disadvantages to maximal testing include requiring participants to go to volitional maximum (1), considerable requirements of time, personnel, and resources (2,39,65), and test performance is frequently limited by local muscle fatigue or pain rather than cardio-respiratory insufficiency (51,91). These disadvantages make maximal testing unfeasible for assessing and screening large populations (66).

The unfeasibility of maximal testing necessitates using a submaximal effort that will give a reliable and valid estimate of an individual's true VO_{2max} (12,90). Tests designed to predict VO_{2max} require an extrapolation of data from a submaximal effort to calculate VO_{2max}. Generally, data obtained from submaximal testing is a measure of the heart rate (HR) response to a submaximal workload. The basic premise of submaximal testing is that a linear relationship exists between HR and oxygen consumption (VO_2) at 50-85% VO_{2max}. Application of a nomogram extrapolation line procedure is used to determine the HR and VO_2 relationship and estimate VO_{2max}. As an individual performs submaximal exercise, VO_{2max} is estimated by drawing a line through several (two or more) steady-state submaximal HR that relate HR and VO_2, then extending this line to an estimated HR maximum. The lower the HR at a given workload, the higher the VO_{2max} will be extrapolated (4,5,15,21). Submaximal field tests designed to predict VO_{2max} use stationary cycles, treadmills, or stepping as the mode of exercise. Advantages to submaximal tests include ease of administration, cost effectiveness, requirement of only submaximal effort, safety, elimination of motivation, and suitability for screening and classifying large groups of individuals in terms of fitness (2,8,51,66,90). Submaximal prediction of VO_{2max} is accurate within 10-27% (r = 0.50-0.92) of the actual measured

value (51,66,79). In general, submaximal testing tends to underestimate the very fit and overestimate the unfit (72,84).

The most commonly used submaximal cycle ergometry (SCE) tests are the single-stage test designed by Astrand-Rhyming (A-R) and the multi-stage tests designed by Sjostrand and the Young Mens Christian Association (2,66,77,79). The A-R test has been modified by the United States Air Force (USAF) for the purposes of assessing the fitness levels of its personnel (58,65,72).

The original A-R SCE was introduced in 1954. The nomogram was developed from 58 subjects (18-30 yr, 27 males, 31 females) who performed a submaximal test on a cycle ergometer and a maximal test on a treadmill. The reported variability was 6.7%-14.4%. Extrapolation of VO_{2max} by means of the nomogram was based on the observations: 1) at 50% VO_{2max} the average HR for males was 128 beats per minute (bpm) and 138 for females, 2) at 70% VO_{2max} the average HR for males is 154 bpm and 164 for females, 3) a common HR for males of 61 bpm and 81 for females at rest, 4) the maximum attainable HR is 195 bpm, and 5) when the HR at steady-state ranges between 125-170, a near linear increase in VO_2 occurs with HR (4,7,8,19,89,90). In 1960, Astrand tested an additional 144 subjects, modified the nomogram, and added an age correction factor. He determined the correlation between measured and estimated VO_{2max} was r = 0.86 for males and r = 0.81 for females when comparing a submaximal cycle test to a maximal cycle test. The standard error was 10-15% (4,8,85). The A-R nomogram is the most researched SCE test. A summary of the studies reviewed, reported a validity ranging from r = 0.54 to r = 0.92 with a SEE ranging from 3.3 to 7.1 ml/kg/min (6-16%). The original A-R nomogram was consistently reported to underestimate measured VO_{2max} (8,21,26,45,47,90).

During the late 1960's and early 1970's, the USAF realized the importance of aerobic fitness and the need for a quantitative assessment of aerobic capacity. The impractical nature of maximal testing led to the acceptance of a 12 minute endurance run. This was later modified to a 1.5 mile run/3.0 mile walk in a set period of time to estimate fitness (61,65,72). In 1992, the USAF adopted SCE to estimate VO_{2max}. It was promoted as a safe, reliable, and valid measure to quantify aerobic fitness. This was done in response to the death of an estimated 2-5 USAF members annually in incidents related to the annual run/walk test. It became apparent that personnel could successfully pass the run/walk test without being aerobically fit. This procedure was deemed unhealthy and unsafe because most USAF members were unaccustomed to intense physical activity and it did not encourage the performance of regular aerobic activity. The theory behind the change to SCE was that it would encourage regular aerobic exercise which would translate to improved force readiness (16,49,61,72).

The USAF SCE is a single-stage submaximal test modified form the original A-R nomogram. United States Air Force SCE is a 8-14 minute test performed on a 818E Monarck mechanically braked cycle at a pedaling cadence of 50 rpm. The test duration is divided into a 2 minute warm-up phase, 3 minute workload selection period, and a 6-7 minute assessment period. The initial workload and all workload adjustments are calculated using a USAF prototype algorithm (Fitsoft 2.1, 1996). The starting workload is based on gender, age, weight, and activity level. The computer uses a regression equation to predict VO_{2max} from the final power output, mean steady-state HR during the last two minutes, height, weight, gender, and an age correction factor. Normative VO_{2max} values used by the USAF to categorize members as aerobically fit or unfit is adapted from Cooper clinic norms (1,58,66).

The research by Hartung, et al. (39,40), Pollock, et al. (65), and Williford, et al. (88) are the only published studies that calculate the validity of the USAF SCE test. The Pollock, et al. (65) study, was commissioned by the USAF to validate the USAF SCE test and is published as a government document. The Pollock study forms the basis for USAF justification of the USAF SCE test. The reported validity of the USAF SCE test has a range from $r = 0.74$ to $r = 0.95$ with a SEE ranging from 4.3 to 6.9 ml/kg/min for males and a range from $r = 0.76$ to $r = 0.85$ with a SEE ranging from 2.3 to 5.5 ml/kg/min for females when compared to a maximal treadmill test. For males the test underpredicted VO_{2max} by a range of 2.2 to 8.1 ml/kg/min. For females, the test overpredicted VO_{2max} by a range of 2.2 to 2.3 ml/kg/min. The Hartung, et al. (39) research, is the only study to determine the test-retest reliability of the USAF SCE test. This study used only women subjects. The reported test-retest reliability for females is $r = 0.92$. There are no reported reliability values for males.

The purpose of this study is to determine the test-retest reliability of the USAF SCE for both male and female populations.

Research Question

Specifically, this study will address the following question:

I. Does the United States Air Force submaximal cycle ergometry test provide a stable measurement of VO_{2max} with repeat testing?

CHAPTER II

REVIEW OF LITERATURE

Determinants of Aerobic Capacity

The ability to perform long-term muscular work is dependent on the body's ability to supply energy. Energy production used for endurance work is dependent upon aerobic metabolism, or the rate of oxygen utilization (VO_2). Maximal rate of oxygen consumption (VO_{2max}), typically expressed in L/min or ml/kg/min, defines maximal aerobic capacity and quantifies an individual's capability for aerobic resynthesis of adenosine triphosphate (6,51,56). VO_{2max} is the primary indicator of aerobic fitness, cardiovascular health, and endurance performance (2,3,22,39,51,93).

During muscular work, VO_2 is related to the intensity and duration of the exercise and the amount of muscle mass required to perform the task. The ability to meet these demands is determined by the cardiovascular system's ability to deliver oxygen to the working muscles and the muscle's ability to utilize the oxygen for energy production (55,62,74). Oxygen delivery is defined as: $Q \times [O_2]a$, where Q is the cardiac output and $[O_2]a$ is arterial oxygen concentration. Cardiac output is defined as the quantity of blood pumped by the heart per minute, is the product of stroke volume and heart rate (HR). Stroke volume is the volume of blood ejected by the left ventricle with each heart beat. Heart rate is the measure of the frequency of contraction.

Normal resting cardiac output for a trained or untrained adult is 4-5L/min. During aerobic exercise, cardiac output can increase up to five fold from resting values in untrained people and up to seven fold from resting values in trained. The increase of metabolism during aerobic exercise requires a concomitant increase in energy substrate and oxygen to the working muscles. This increased demand is met by an increase in cardiac output. Distribution of cardiac output throughout the body is largely determined by metabolic demand. At rest, 15-20% of cardiac output is distributed to skeletal muscle. During aerobic exercise, as much as 85% of cardiac output may be directed to the working muscles. These percentages remain unchanged with training. Endurance (aerobic) training does increase cardiac output, so blood flow to working muscles will increase.

Arterial oxygen concentration ($[O_2]a$) is determined by the hemoglobin concentration of blood and barometric pressure. Oxygen binds to the hemoglobin in the lungs and is delivered to peripheral tissues. Approximately 97% of hemoglobin in arterial blood is bound with oxygen at sea level. The binding of oxygen to hemoglobin is unchanged with training and arterial hemoglobin saturation levels are equal in trained and untrained people. Normal hemoglobin concentration is 15 mg/dl.

Oxygen delivery to working muscles is determined by peripheral blood flow. Oxygen use by muscle depends upon their aerobic enzyme capacity and mitochondrial concentration. The activity of aerobic enzymes and amount of mitochondria directly

effect oxygen uptake at the muscle cellular level. Endurance training increases the amount of mitochondria and aerobic enzyme activity. This directly increases oxygen utilization by muscles during exercise.

Venous blood exiting working muscle has less oxygen concentration than arterial blood. This is known as the a - vO_2 difference. VO_2 is determined by oxygen delivery and utilization, summarized by Fick's equation: $VO_2 = Q \times (a - vO_2)$, where Q is the muscular blood flow and a-vO_2 is the arteriovenous difference across the muscle. To increase VO_2, muscle blood flow must increase and/or the arteriovenous difference must increase. The level of VO_2 attained during exercise is determined by the demand placed on the body (2,8,34,51,54,65).

Reproducibility and Validity of VO_{2max} as a Measure of Aerobic Capacity

The traditionally accepted criterion measurement of aerobic capacity or "gold" standard is directly measured VO_{2max}. Maximal treadmill or cycle ergometer laboratory tests are highly reproducible ($r = 0.95$-0.98) with a standard error of the estimate (SEE) of 1-3 ml/kg/min. The next hierarchy of tests are maximal treadmill or cycle ergometer tests, which estimate VO_{2max} from exercise time or maximal power output and correlate highly with actual VO_{2max} ($r = 0.90$-0.95, SEE 3-5 ml/kg/min) (2,5,6,51,55,56,57,64,70).

Factors that Affect Aerobic Capacity

State of Training

The VO_{2max} difference between trained and untrained individual's is between 5-20%

(51). Endurance training can increase aerobic capacity by 15-30% during an initial three month training period and by as much as 50% over a two year period (51,66). Training improves the body's ability to extract oxygen from blood. This improvement results in an increase in arteriovenous difference and more effective distribution of the cardiac output (34,54). Improvement in the mitochondrial oxidative capacity is primarily responsible for improvement in aerobic capacity (51).

Heredity

The genetic effect on an individual's VO_{2max} is between 10-30%, 50% for maximum heart rate, and 70% for physical working capacity (14,15). Endurance training improves an individual's aerobic capacity, but genetic endowment limits this improvement. Due to genetic limits of aerobic performance, it is impossible to predict an individual's response to a training regimen (51).

Gender

The VO_{2max} for females is 15-30% lower than for males (64,84). These gender differences are generally attributed to body composition and hemoglobin concentration. Males generally have more fat free mass than women and are able to generate more aerobic energy. Males have a 10-14% greater concentration of hemoglobin and are able to circulate more oxygen during aerobic exercise (51,54,64). Males and females exhibit equal adaptation to aerobic training (64).

Age

After age 25, VO_{2max} declines steadily at a rate of approximately 1% (~.5 ml/kg) per year. An inactive individual's rate of decline may be doubled (8,51). Evidence indicates that an individual's activity level over time has a far greater effect on the rate of decline than aging alone (2,34). For an individual whose level of physical activity and body composition remain constant over time the rate of decline may be only 1/2% (~.25 ml/kg) per year. As much as 50% of the steady decline may be attributable to a decrease in stroke volume (51,54).

Altitude

Aerobic capacity is not measurably altered at altitudes below 1,500 meters. Above 1500 meters there is a 10% linear decline in VO_{2max} per 1,000 meter increase in altitude (51). The decrement of aerobic capacity past 1,500 meters is due largely to hypoxia. A reduction in barometric pressure decreases the hemoglobin oxygen saturation and oxygen partial pressures, creating hypoxia and ultimately limiting VO_{2max} (34,48).

Body Composition

Differences in body composition cause an estimated 69% variation in VO_{2max} scores among individuals. This large estimated variability has led to the common practice of expressing oxygen uptake measures in terms of body weight (37,38,51). The level of aerobic capacity is ultimately related to the percent and trained state of fat-free mass. An individual with higher levels of body fat will have a lower level of VO_{2max} (37,63).

Mode of Exercise

An important determinant in the measurement of VO_{2max} is the quantity of the muscle mass stressed when performing the task or mode of exercise used to elicit maximal oxygen uptake. The greater the amount of muscle mass employed during exercise the greater the consumption of oxygen (9,62,64). The highest VO_{2max} values are usually obtained during treadmill running (37,51). Bench stepping produces VO_{2max} values similar to the treadmill (30,38,74). VO_{2max} measured during cycling is 10-25% less when compared to a treadmill (38,46,48). Arm ergometry is 30% less and swimming is 20% less when compared to a treadmill (9,51,52).

Assessment of Aerobic Capacity

When assessing aerobic capacity, testers must choose a type of exercise involving a large group of muscles and be of sufficient intensity and duration to cause an adjustment in the cardio-respiratory system to the level of the exercise (7,74,91). Testers have used a variety of exercises in the development of aerobic performance tests. The typical exercise modes include treadmill running and walking, endurance runs and walks, stationary cycling, arm cranking, bench stepping, and swimming (3,10,66,74). To measure aerobic capacity a specific performance test will be employed to obtain a VO_{2max} value, typically expressed in ml/kg/min. VO_{2max} is measured by maximal test (direct measurement) or submaximal test (estimation or prediction) (2,3,31,91).

Maximal Exercise Testing

The criterion measure or "gold" standard of aerobic capacity is the direct measurement of VO_{2max} (2,5,6,51,57,70). Measurement of VO_{2max} is a laboratory procedure involving maximal cycle or treadmill exercise and direct analysis of expired respiratory gases via open or closed circuit spirometry. It usually takes one hour to administer, requires expensive laboratory equipment, and a technical staff of at least two (2,39,40,65). During maximal exercise, VO_{2max} can be directly measured by analysis of expired gases or estimated using prediction equations. The direct analysis of expired gases is the most accurate of the two methods. The direct analysis of gases is generally reserved for research settings, while the use of estimating from maximal testing, the next most accurate method of measuring VO_{2max}, is used for field testing (2,10,74). Maximal testing is associated with a certain medical risk in unscreened, untrained, and older individuals (31,40,66). Retrospective data from more than 500,000 tests showed a mortality rate of 1:500,000 and a myocardial infarction rate of 3-5:20,000 tests (2,65). Mortality and morbidity rates are significantly less in younger, healthy, screened, trained, and submaximally tested populations (31,65).

Accurate assessment occurs only when participants go to volitional maximum or exhaustion. Typically, a high level of motivation and anaerobic output is required to complete the test (91). The participant is usually the one who terminates the exercise. Criteria used to ensure an individual has reached maximum include: 1) plateau in VO_2

with increase in workload, 2) respiratory exchange ratio (RER) of greater than 1.1, 3) serum lactate levels of greater than 8 mmol/ml, 4) heart rate approaching or at age predicted maximum, or 5) rating of perceived exertion (RPE) greater than 17 (65,66,90). Disadvantages to maximal testing include requiring participants to go to volitional maximum (1), considerable requirements of time, personnel and resources (2,39,40,65), and test performance limited by local muscle fatigue or pain rather than cardio-respiratory insufficiency (51,91). These disadvantages make maximal testing unfeasible for large populations and is usually reserved for diagnostic or research purposes (66).

Submaximal Exercise Testing

The unfeasibility of maximal testing necessitates using a submaximal effort that will give a reliable and valid estimate of an individual's true VO_{2max} (12,90). Tests designed to predict VO_{2max} require an extrapolation of data obtained from a submaximal effort to calculate VO_{2max}. Data obtained includes performance measures of duration and distances from walking and running tests or from heart rate measured during or immediately after exercise performed on a bicycle ergometer, treadmill, or step test. Advantages of submaximal tests include ease of administration, cost effectiveness, requirement of only submaximal effort, and safety. In addition, motivation is eliminated as a factor and submaximal testing is well suited for screening and classifying large groups of individuals in terms of aerobic fitness (2,3,8,51,65,66,90).

Predictions based on heart rate make use of a linear relationship between heart rate

and oxygen consumption during aerobic exercise of light to moderately heavy intensities (51,66). Stroke volume plateaus at approximately 40-50% VO_{2max} (65). The major increase in cardiac output between 50-100% VO_{2max} is due to increased heart rate (8,34). Application of an extrapolation line procedure is utilized to determine the heart rate and oxygen consumption relationship and estimate VO_{2max}. As an individual performs submaximal exercise, VO_{2max} is estimated by drawing a line through several (two or more) steady-state submaximal heart rates that relate heart rate and oxygen consumption, then extending this line to an estimated heart rate maximum. Lower heart rates at a given submaximal workload will extrapolate to higher VO_{2max} (2,8,51,65,66).

The accuracy of the prediction of VO_{2max} is limited by the following assumptions: 1) The linear relationship between heart rate and oxygen consumption is constant. This premise is met to a large degree between 50-85% of VO_{2max}. Heart rate reaches its maximum at a lower workload than VO_2 indicating a larger than expected consumption of oxygen. Beyond 85% VO_{2max}, the asymmetric relationship between VO_2 and HR causes a underestimation of VO_{2max}. 2) Maximum heart rates are similar for individuals of the same age. This assumption is not always met. The standard deviation of maximum heart rate for individuals of the same age is approximately +/- 10-12 beats per minute (bpm). This variability in heart rate can cause a significant under or over estimation of VO_{2max} when using a heart rate and oxygen consumption extrapolation line procedure. Another potential source of error is not accounting for the decrease in maximal heart rate

associated with aging. 3) The exercise economy or mechanical efficiency is constant for all individuals. The variability in mechanical efficiency for walking and cycling is approximately 6% and 10% for bench stepping. This variability can cause an underestimation in an individual with poor exercise economy and overestimate someone with high exercise economy. 4) The day to day variations in submaximal heart rate are insignificant. This assumption is not always met. The variability is approximately +/- 5 bpm (8,51,66,75,79,90). However, this is considered insignificant because during a test of VO_{2max} the oxygen consumption per heart beat is evaluated (8,12). Submaximal prediction of VO_{2max} is accurate within 10-20% of the actual value (51,66,79).

Factors Affecting the Prediction of VO_{2max} from Submaximal Exercise Testing

Seat Height

Individual differences in leg length requires standardized criteria for seat height measurement to optimize pedaling efficiency and VO_2. Three common styles of measurement exist: 1) pubic symphysis to floor, 2) greater trochanter to floor, and 3) ischium to floor. Appropriate seat heights in terms of optimizing VO_2 are: 1) 109% of pubic symphysis height, 2) 100% of greater trochanter height, and 3) 103% of ischial height. A seat height variation of greater than 5% is needed to produce significant differences in VO_2 at submaximal workloads. Inappropriate adjustment of seat height can alter submaximal estimation of VO_{2max} (59,65,73).

Circadian Rhythm

The cyclical variation in the functional activities of most biological tissues has a periodicity of approximately 24 hours. Examples of such rhythms include regular fluctuations in body temperature, level of arousal, blood composition, adrenocortical secretory activity, and cardiorespiratory variables of HR, VO_2, and VO_{2max}. The studies referenced reported that error arising from time of day HR/VO_2 variation is significantly different from random day-to-day variation in the estimation of VO_{2max} from HR and VO_2. Effects of diurnal variation on submaximal performance parallels the diurnal variation in body temperature. The variation in body temperature is considered the most important variable in diurnal HR variation. The variation observed from submaximal prediction of VO_{2max} is approximately 350ml/min (24,26,42,68,83).

Caffeine

The potential ergogenic effect of caffeine ingestion on endurance performance is blunted or nonexistent with submaximal estimation of VO_{2max}. Caffeine is a stimulant of the cardiovascular and nervous systems. Peak plasma concentrations of caffeine are reached approximately 1 hour after ingestion.

Stimulation of the cardiovascular system is primarily mediated by a catecholamine release of epinephrine. This stimulant effect, although of short duration, will increase resting HR if ingested prior to testing. An increase in resting HR may skew the HR-VO_2 predictions equation resulting in underprediction of VO_{2max}. The effect of cardiovascular

stimulation is blunted in the habitual caffeine user. The effect of caffeine ingestion on submaximal testing has not been studied. The literature has only evaluated the effects with maximal testing and long duration (60-90 min) exercise performance. The effect on submaximal testing has only been postulated within these research articles (11,28,29,33,49).

Neural stimulation causing an increase in irritability coupled with pre-test anxiety may be more detrimental to submaximal testing than cardiovascular stimulation. The effects of pre-test anxiety and caffeine ingestion would result in an underprediction of VO_{2max} with submaximal testing. The effects of neural irritability are blunted in the habitual caffeine user (11,28,29,47). In 1995, Lombard, determined that employment of anxiety reduction techniques resulted in a decrease in resting HR by 10% and a mean increase in estimated VO_{2max} of 2.0 ml/kg/min (49).

Warming Up

Activity specific warm-up is beneficial to performance of heavy work or intense exercise. Warm-up improves the body's physiologic and psychological state of readiness to rapidly and effectively adjust at the onset of exercise. Physiologically, warm up does not produce a favorable influence on submaximal estimation of VO_{2max}. Psychologically, a period of warm-up may reduce or eliminate an elevated resting HR produced by pre-test anxiety. Literature evaluating the effects of warming-up on submaximal estimation of VO_{2max} is limited and should not be considered conclusive (18,49,69,82,92).

Smoking

The chronic and acute effects of cigarette smoking reduce exercise performance. However, a paradox exists between a smokers' maximal exercise capacity and response to submaximal exercise. Chronic smokers have a significantly less maximal test duration than nonsmokers. However, smokers have a longer exercise duration in response to a submaximal workload. This appears to be due to a lower beta$_2$-adrenoreceptor density compared to nonsmokers. A decrease in beta$_2$-adrenoreceptor density would result in a decrease in heart rate response to submaximal exercise. Chronic smoking appears to blunt the heart rate response to submaximal exercise, resulting in a overprediction of VO_{2max} in submaximal testing (23,46,65,76).

Pedaling Frequency

Maintaining the appropriate pedaling frequency is critical to submaximal testing. Deviations from the established protocol can cause exponential changes in minute ventilation and VO_2 and linear changes in HR. Pedaling frequency and workload directly effect changes in HR and VO_2 during submaximal testing. Pedaling frequencies between 30-80 revolutions per minute (rpm) have been shown to be the most economical in terms of VO_2. Typically, submaximal testing is performed at 50 rpm (20,35,36,41,50,53,86).

A variety of submaximal field tests have been designed to predict VO_{2max} utilizing treadmills, stationary cycles, and stepping as modes of exercise. The most commonly used cycle ergometry tests are the single-stage test designed by Astrand-Rhyming (A-R)

and the multi-stage tests developed by Sjostrand and the Young Men's Christian Association (YMCA) (2,66,77,79). The A-R test has been modified by the United States Air Force (USAF) for the purposes of assessing the fitness levels of its personnel (58,65,72). The following sections are dedicated to the Astrand-Rhyming test and the USAF submaximal cycle ergometry (SCE) testing program.

Astrand-Rhyming Nomogram

The original A-R nomogram was introduced in 1954. This indirect predictive test is based on the linear relationship between HR and VO_2. VO_{2max} is estimated from adjustments in the HR in response to a submaximal workload (7,32,47,90). The original nomogram was developed from 58 subjects (18-30 yr, 27 males, 31 females) who performed a submaximal test on a cycle ergometer and a maximal test on either a treadmill or a cycle ergometer. Extrapolation of VO_{2max} by means of the nomogram was based on the observations: 1) at 50% VO_{2max} the average HR of males was 128 bpm and 138 for females, 2) at 70% VO_{2max} the average HR for males is 154 bpm and 164 for females, 3) a common resting HR for males is 61 bpm and 81 for females (4,7,8,19,85,90), 4) the maximum attainable HR is 195 bpm, and 5) when the HR at steady-state ranged between 125-170, a near linear increase in VO_2 occurs with HR (7,8,89).

Astrand and Rhyming (1954) reported a variability of 6.7% (.023 +/- .059 L/min) for males at a 1200 kgm/min workload and 9.4% (.010 +/- .051 L/min) for females at a 900 kgm/min. At lower workloads of 600 kgm/min for females and 900 kgm/min for

males the variability increased to 14.4% and 10.4% respectively when compared to maximal treadmill tests (7). In 1960, Astrand tested 144 additional subjects (100 males, 44 females), modified the nomogram, and introduced an age correction factor. He determined correlation coefficients (r) of $r = 0.86$ for males and $r = 0.81$ for females when comparing a submaximal cycle test to a maximal cycle test. The standard error was 10-15% (4,8,21,85).

In 1962, Borg and Dahlstrom, used 78 healthy male subjects (20 yr) to calculate the validity and re-test reliability of the A-R SCE test versus maximal cycle ergometry. They determined the correlation between measured and predicted VO_{2max} was $r = 0.54$ and the re-test reliability was calculated at $r = 0.95$ (13).

In 1964, Glassford, et al., used 24 healthy male subjects (17-23 yr) to calculate the validity of the A-R SCE test versus a direct treadmill test. They determined the correlation between measured and predicted VO_{2max} was $r = 0.80$ with a standard deviation (SD) of 10.7 ml/kg/min from a workload of 900 kpm/min (32).

In 1965, deVries and Klafs, used 16 healthy male subjects (20-26 yr) to calculate the validity of the A-R SCE test versus maximal cycle ergometry. They determined the correlation between measured and predicted VO_{2max} was $r = 0.74$ (SEE .36 L/min, 9.3%) from a work load of 900 kpm/min at a pedaling frequency of 60 rpm. The typical A-R protocol utilizes a 50 rpm pedaling frequency; this difference probably decreased the tests' correlation (27).

In 1966, Teraslinna, et al., used 31 sedentary male subjects (23-49 yr) to calculate the validity of the A-R SCE test with and without using the A-R age correction factor versus maximal cycle ergometry. They determined the correlation between measured and predicted VO_{2max} increased from r = 0.69 to r = 0.92 when the A-R age correction factor was employed at a workload of 900 kgm/min. This study demonstrated the importance of the age correction factor (80). In 1967, Von Doblen used the A-R SCE protocol and adjusted the A-R age correction factors in a study 84 male subjects (30-70 yr). The predicted VO_{2max} versus a maximal treadmill test had a 13 % standard error of the estimate (SEE). No correlation coefficient was given by this study (85). The Von Doblen age correction was subsequently found to underestimate measured VO_{2max} (19).

In 1968, Davies used 80 healthy male subjects (20-50 yr) to re-examine the linear relationship between HR and VO_2. The validity of the A-R test was calculated versus maximal cycle ergometry. Predicted VO_{2max} values were obtained from two submaximal tests. The first test maintained the HR between 120-150 bpm, while the second test maintained the HR greater than 165 bpm. The lower submaximal HR produced an error of .84 +/- .61ml/min, while the error was reduced at the higher HR to .62 +/- .42. Davies determined the correlation between measured and predicted VO_{2max} was r = 0.72 with a SEE of 15% was associated with submaximal prediction and grossly underestimated VO_{2max} by as much as 1200 ml (26). He disputes the findings of Wyndham (90) and Astrand (4) regarding the linear relationship between HR and VO_2 (26).

In 1970, Oja, et al., used 48 healthy males (29-37 yr) to predict the validity of A-R SCE test versus maximal cycle ergometry. They determined the correlation between measured and predicted VO_{2max} was r = 0.54, with a SEE of 5.6 ml/kg/min at a 900 kpm/min workload. It was concluded that the A-R test predicted the oxygen uptake capacity more accurately when fat free mass, instead of total weight, was used in the prediction equation (60).

In 1974, Jessup, et al., used 40 healthy male subjects (18-23 yr) to predict the validity of A-R SCE test versus a Balke maximal treadmill test. They determined the correlation between measured and predicted VO_{2max} was r = 0.64, with a SEE of 5.7 ml/kg/min at a 600 kpm/min workload (44). In 1975, Jessup, et al., used 60 healthy male subjects (18-23 yr) to predict the validity of A-R SCE test versus a Balke maximal treadmill test and validate a workload selection procedure. They determined the correlation between measured and predicted VO_{2max} was r = 0.65, with a SEE of 4.1 ml/kg/min (9%) at a 600 kpm/min workload. The test was repeated until a subject's mean HR during the last two minutes of the test was greater than 160 bpm (43). In 1977, Terry et al., duplicated this study (81). These three studies confirmed the findings of Davies (26), that the accuracy of prediction improved at HR of greater than 160 bpm.

In 1975, Williams used 31 healthy, young female subjects to determine the test-retest reliability of the A-R SCE nomogram. She determined the reliability coefficient was r = 0.64 from two trials in one day. When three trials were performed

over a three day period, the reliability improved to r = 0.80. When six trials were performed over a six day period, the reliability improved to r = 0.90 (87).

In 1976, Coleman used 15 healthy male subjects (20-23 yr) to calculate the validity of the A-R SCE test versus a Bruce maximal treadmill test. He determined the correlation between measured and predicted VO_{2max} was r = 0.68, with a SEE of 8.6 ml/kg/min (14.3%). The HR values during the last minute of the test were greater than 160 bpm. This study also compared the single-stage A-R test with a modification of the Maritz (r = 0.84) multi-stage submaximal test. They concluded that the use of a multi-stage test was a more accurate predictor of VO_{2max} (21).

In 1981, Cink and Thomas, used 40 healthy male subjects (18-33 yr) to calculate the validity of the A-R SCE test versus maximal cycle ergometry using the age correction factors developed by A-R and Von Doblen. They determined the correlation between measured and predicted VO_{2max} was r = 0.83 (SEE 5.7 ml/kg/min) for A-R and r = 0.84 (SEE 5.5 ml/kg/min) for Von Doblen. Also, the re-test reliability coefficient of the A-R test was calculated to be r = 0.87 using the A-R age correction factors. This study duplicated the testing protocol used in the Teraslinna (80) study, finding a lower correlation coefficient between measured and predicted VO_{2max} when using the A-R age correction factor (r = 0.92 vs. r = 0.83) (19).

In 1982, Siconolfi, et al., used 113 healthy subjects (10 males and females per decade from 20-70 yr) to calculate the validity of the A-R SCE test versus maximal cycle

ergometry. The original single-stage A-R protocol was modified into a multi-stage protocol with a lower beginning workload for all women and men over 35 years of age. VO_{2max} was estimated from the original A-R nomogram and A-R age correction factors. They determined the correlation between the measured and estimated VO_{2max} ranged from $r = 0.92$ to 0.93 for all groups. This study validated the increased accuracy of a multi-stage protocol (75).

In 1984, Kasch, used 83 male subjects (30-66 yr) to calculate the validity of the A-R SCE test versus a maximal cycle ergometry test by Sjostrand. He determined the correlation between measured and predicted VO_{2max} was $r = 0.58$, with a SEE of 6.2 ml/kg/min (16%) (45).

In 1986, Legge and Bannister, used 25 healthy male subjects (20-29 yr) to calculate the validity of the original A-R nomogram and a modification of the original A-R nomogram versus maximal cycle ergometry. The new nomogram was based on the linear relationship between VO_2 and the elevation in HR above that reached during zero-load pedaling. They determined the correlation between measured and predicted VO_{2max} was $r = 0.98$ with a SEE of .17 L/min for the modified nomogram and $r = 0.80$ with a SEE of .51 L/min for the original. They concluded that this modified nomogram may have application with individuals whose tests are adversely effected by higher resting HR (47).

In summary, of the studies reviewed, reported validity of the A-R nomogram has a range from $r = 0.54$ to $r = 0.92$ with a SEE ranging from 3.3 to 7.1 ml/kg/min (6-16%).

The original A-R nomogram was consistently reported to underestimate measured VO_{2max} (8,21,26,45,47,90).

The A-R SCE is a single-stage, 6 minute test. All testing is performed on a Monark cycle ergometer at a pedaling frequency of 50 rpm. Workload is based on gender and activity level of the subject. For males, workload is set at 150 watts (w) if well trained, 100w if moderately trained, and 75w if untrained. For females, workload was 100w, 75w, and 50w, respectively. The workloads are selected to elicit a HR between 125 and 170 bpm. Heart rate is measured within the last 15 seconds of minutes 5 and 6. If the last two HR differ by more than +/- 5 beats, the test is continued until the last two HR are within +/- 5 beats of each other. The test is terminated if the HR of the last two minutes do not differ by more than +/- 5 beats and the mean value of the last two HR is between 125 and 170 bpm. The average of the last two HR with the corresponding workload is used to estimate VO_{2max}. Estimation of VO_{2max} is by extrapolation of a fitted straight line to an age predicted HR maximum on the A-R nomogram. The calculated value is then corrected for age (7,8,47,79,89).

Submaximal Testing by the USAF

The United States Air Force has used a 12 minute endurance run or a timed 1.5 mile run/3.0 mile walk to estimate fitness since 1970. In 1991, Sharp suggested that individuals be screen by a medical practitioner to eliminate at risk individuals prior to performing the 1.5 mile run (61,72). This was based on the fact that an estimated 2-5

USAF members died annually in incidents related to the annual fitness test (1,72,88). Since 1992, the USAF has employed a submaximal cycle ergometry (SCE) test to estimate VO_{2max} (16,61,65).

In 1993, Hartung, et al., used 22 adult males (26-45 yr) to determine the validity of the USAF SCE test to predict VO_{2max} versus a maximal treadmill test. The 22 subjects were divided into two groups: 11 aerobically trained runners and 11 who were relatively sedentary. They determined, for all subjects, that there was a high correlation (r = 0.95, SEE 4.25 ml/kg/min) between estimated and measured VO_{2max}. The test underpredicted VO_{2max} by 8.1 ml/kg/min, 23% in the sedentary group and 12% in the group of trained runners (40).

In 1994, Williford, et al., used 50 male USAF officers (35-43 yr) to calculate the validity of the USAF SCE test versus a Bruce maximal treadmill test. They determined the correlation between measured and predicted VO_{2max} was r = 0.74 (SEE 6.9 ml/kg/min) and an underprediction of VO_{2max} by 8.0 ml/kg/min (88).

In 1994, Pollock, et al., used 207 subjects (males, n=103; females, n=104) between the ages of 18-54 years to determine the accuracy of the USAF SCE test versus maximal treadmill. For males, they determined the correlation between measured and predicted VO_{2max} was r = 0.85 (SEE 6.7 ml/kg/min) and an underestimation of VO_{2max} by 2.2 ml/kg/min. For females, the correlation between measured and predicted VO_{2max} was r = 0.85 (SEE 5.5 ml/kg/min) and an overestimation of VO_{2max} by 2.2 ml/kg/min (65).

In 1995, Hartung, et al., used 37 healthy women (17-47 yr) to calculate the validity and re-test reliability of the USAF SCE test against maximal treadmill and cycle ergometer tests. They determined the re-test reliability coefficient of SCE to be r = 0.92. The SCE overestimated VO_{2max} when compared to the treadmill by 8.5% (r = 0.76, SEE .23 L/min) and overestimated when compared to the maximal cycle ergometry test by 18.5% (r = 0.70, SEE .34 L/min) (39).

In summary, reported validity of the USAF SCE test has a range from r = 0.74 to r = 0.95 with a SEE ranging from 4.3 to 6.9 ml/kg/min for males and a range from r = 0.76 to r = 0.85 with a SEE ranging from 2.3 to 5.5 ml/kg/min for females when compared to a maximal treadmill test. For males, the test underpredicted VO_{2max} by a range of 2.2 to 8.1 ml/kg/min. For females, the test overpredicted VO_{2max} by a range of 2.2 to 2.3 ml/kg/min (39,40,65,88). The research by Hartung , et al. (39,40), Pollock, et al. (65), and Williford (88) are the only published studies that calculate the validity of the USAF SCE test. The Pollock, et al., study (65) was commissioned by the USAF to determine the validity of the USAF SCE test and is published as a government document. The Pollock study forms the basis for USAF justification of the USAF SCE test. The Hartung, et al. (39) research, is the only study to determine the test-retest reliability of the USAF SCE test. This study only used women subjects.

The USAF SCE test is a modification of the A-R SCE test. USAF SCE is a single stage, 8-14 minute test. All cycle ergometry is performed on a Monark 818E cycle

ergometer at a pedaling cadence of 50 rpm. Subjects listen to a metronome set at 100 bpm to coincide with each pedal stroke. Seat heights are adjusted to approximately 100% of heel to trochanter length (65,88). The initial workload (power output), as well as all workload adjustments, is calculated using a USAF prototype algorithm (Fitsoft 2.1, 1996). The starting workload is based on gender, age, weight, and activity level. The USAF software classifies a person as active if they participate in strenuous physical activity for thirty minutes at least three times per week (1). Heart rate is measured with a polar pacer wireless HR monitor. The test is conducted in a 80 square foot area (8X10 room), climate controlled to between 68-72 degrees, and free of environmental noise and visual distraction. Data is recorded into the computer (IBM 486) by a trained test administrator (17,39,49,65).

A two minute warm-up period precedes the start of the test. Subjects begin pedaling at 50 rpm while a resistance, 0.5 kiloponds (kp) for women and 1.0 for men, is added. Following the warm-up period, the test begins with a 3 minute workload adjustment period to elicit a steady-state HR > 125 bpm. The software may increase workload after every minute during the initial three minute period. The final 6 minutes of the SCE test are performed at a constant workload. Heart rate is collected during the last 10 seconds at the end of each minute of exercise. A seventh minute is added if the final two HR (minutes 5 and 6) differ by more than +/- 5 bpm. A HR exceeding 85% HR maximum (220-age) will invalidate the test (39,40,49,65). The computer utilizes a

regression equation to predict VO_{2max} from the final power output, steady-state HR during the last two minutes, height, weight, gender, and an age correction factor (1,17,65). Normative VO_{2max} values used by the Air Force to categorize members as aerobically fit or unfit is adapted (rounded to whole numbers) from Cooper clinic norms (1,58,66).

CHAPTER III

METHODS

SUBJECTS

RECRUITMENT

Each Air Force member annually performs the USAF submaximal cycle ergometry (SCE) test with their squadron (unit). Subjects were randomly selected from squadrons testing during the data collection period. Those agreeing to participate were given an explanation of the project and asked to sign a consent form (Appendix A).

INCLUSION CRITERIA

1. Must be active duty Air Force personnel.
2. Must be performing their annual cycle ergometry test.
3. Must be males and females, 18-50 years old.
4. All re-tests must be performed not less than 24 hours and not greater than 7 days after the initial assessment.

EXCLUSION CRITERIA

1. Pregnancy
2. Physical profile restriction against cycling
3. Hospitalization or medical confinement to quarters within the last five days
4. Taking beta blockers

5. Using nicotine patches or gum

6. Donated blood within last 72 hours

7. Answers "YES" to any questions on the Fitness Assessment Screening Questionnaire (Appendix B).

PROCEDURE

ADMINISTRATIVE PREPARATION

At least five to seven days prior to the scheduled cycle ergometry assessment, each subject received a Fitness Assessment Screening Questionnaire (Appendix B) and Fitness Assessment Preparation Handout (Appendix C). The preparation handout makes recommendations to the subject for achievement of the best results. The assessment did not begin until the subject had read and signed the screening questionnaire.

ASSESSMENT PREPARATION

During the assessment subjects were instructed to wear comfortable, light exercise shoes and clothing. Females were instructed not to wear metal underwire bras because of possible interference with the heart rate monitor. Height was measured to the nearest 1/4 inch with a wall mounted Stadi-O-Meter (Noval Products Inc., Addison, IL) and weight to the nearest 1/4 pound with a Health-O-Meter scale (Health-O-Meter Inc., Bridgeview, IL) by the fitness assessment monitor (FAM). Subjects removed their shoes for both the height and weight measurements. Two pounds were subtracted from the subjects' weight measurement for fitness attire.

INSTRUMENTATION

The FAM applied, adjusted, and calibrated all equipment prior to and during the assessment. Heart rate was monitored using a Polar Pacer (Polar CIC, Port Washington, NY) wireless heart rate monitor and displayed on a wristwatch receiver. Subjects were instructed to secure the chest strap and transmitter snugly, directly under the pectoral muscles. The wristwatch receiver was kept within 3 feet of the transmitter to ensure a good signal (Appendix D). All cycle ergometry was conducted using a Monark 818E friction braked bicycle ergometer (Monark, Stockholm, Sweden), without peddle straps. The cycle ergometer was calibrated prior to each test using the USAF field calibration method (Appendix E). Seat height was adjusted to 100% of each subjects' heel to trochanter length. This was accomplished by having the subject sit upright on the saddle with one heel on a pedal that is at the bottom of the peddle stroke. The seat was adjusted so that the subject's leg was fully extended. Seat height was constant for all tests. Seat height was adjusted in accordance with USAF protocol (Appendix F). The handle bars were adjusted to a comfortable position that did not allow the subject to slump or lean forward. Subjects were instructed to ride in an upright, sitting position during the entire test. Pedaling cadence was constant at 50 rpm for all tests. Subjects paced their cadence with an electronic metronome set at 100 bpm to coincide with each pedal stroke. Air Force submaximal cycle ergometry uses a UASF prototype interactive computer software package (Fitness Program Assessment Software, Fitsoft 2.1) to determine initial

workload, adjustments in workload during the three minute workload adjustment period, and to perform all calculations necessary to compute the predicted VO_{2max}. The FAM recorded all data collected during the assessment into the computer. The FAM is an individual who is specifically trained to administer the fitness assessment.

FACILITY/ENVIRONMENTAL REQUIREMENTS

Each assessment station was separated by partitions at least seven feet in height and contain 80 square feet (8X10). Room temperature was kept between 68 and 72 degrees Fahrenheit. If room temperature exceeded 75 degrees Fahrenheit, the FAM terminated the assessment. The assessment area was kept free of noise and visual distractions. No one was allowed to coach the subject.

ASSESSMENT

The assessment period was 8-14 minutes in duration. During the initial two minutes the subject remained seated with feet resting on the pedals. This allowed the subject to relax and to obtain a starting heart rate below 110 bpm. If the resting heart rate was below 110 bpm, the subject began a two minute warm-up period.

Subjects began pedaling at 50 rpm while the FAM added resistance, 0.5 kp for females and 1.0 kp for males, by turning the workload adjustment knob to tighten the brake belt. One kilopond is equivalent to one kilogram of weight. After the two minute warm-up, the subject began a three minute workload adjustment period.

The three minute workload adjustment period is used to regulate the workload to a

level that elicits a heart rate greater than 125 bpm. The computer algorithm adjusts the workload during the last 5 seconds of each of the three minutes until a heart rate of 125 bpm is attained. The initial workload (kp) was calculated by using age, gender, weight, and activity level (Appendix G). The USAF protocol defines an individual's activity level as active if they perform strenuous physical activity for at least 30 minutes, three times weekly. During the last five seconds of each minute the computer control algorithm prompted the FAM to record the heart rate into the computer. If required, the computer control algorithm prompted the FAM during the initial 10 seconds of the 60 second cycle to increase the workload. The FAM increased the workload only when the subject's heart rate is less than 125 bpm (Appendix G).

The 6-7 minute assessment phase began when the subject attained a heart rate of 125 bpm. During the assessment phase subjects continued to pedal at 50 rpm at the workload determined during the adjustment period. During the last five seconds of each minute the computer control algorithm prompted the FAM to record the heart rate into the computer. The FAM added a seventh minute if the final two heart rates (minutes 5 and 6) differed by more than +/- 3 bpm. The FAM terminated the test if: 1) the subject's heart rate exceeded 85% maximum heart rate, 2) the subject's heart rate did not exceed 125 beats during the workload adjustment period, 3) the subject was unable to pedal at 50 rpm, or 4) the subject requested termination. When the assessment was completed a cool down period was initiated. The FAM reduced the workload to 0.5 kp, for both males and

females, until the subject's heart rate went below 120 bpm. When cool down was completed the subject dismounted from the cycle.

DATA COLLECTION

The computer algorithm calculated the predicted VO_{2max} from the final workload, mathematical average of steady-state heart rate during the last two minutes, height, weight, gender, and an age correction factor. The predicted VO_{2max}, in whole numbers, was given in terms of milliliters of oxygen consumed per kilogram of body weight per minute (ml/kg/min). The FAM recorded the predicted VO_{2max} value into the computer database and gave the subject a hardcopy (Appendix H). Air Force fitness standards in VO_{2max} values as predicted by submaximal cycle ergometry (Appendix I). Two assessments were administered on each subject. The second assessment was performed not less than 24 hours and not more than seven days after the initial assessment.

No names or identifying numbers were used in any report or publication. All records are confidential. All information collected on Air Force members is protected from disclosure by: 1) Federal Privacy Act of 1974, 5 U.S.C. 552a and its implementing regulation, and 2) Air Force Instruction 40-501 (1).

DATA ANALYSIS

Descriptive statistics, including mean and standard deviation were calculated for all subjects for each SCE test and the absolute difference in SCE between tests. These statistics were further partitioned by gender.

Inferential statistics, including intraclass correlation coefficient (ICC), 95% confidence interval for a population mean (CI), and standard error of the measurement (SEM) were calculated for all subjects for each SCE test and for the absolute difference between SCE tests. These were further partitioned by gender. A repeated measures analysis of variance (ANOVA) was calculated to provide the means square error terms required to determine the ICC and SEM. The ICC was used to determine the between subject variability.

$$ICC\ (2,1) = \frac{BMS - EMS}{BMS + (k - 1)EMS + \frac{k(RMS - EMS)}{n}}$$

The SEM was calculated to determine the stability of the within-subject error measure between tests. The SEM expresses measurement error in the same units as the original measurement and it is not influenced by variability between subjects. The SEM is equal to the square root of the mean square error term from the calculated ANOVA. A 95% CI was estimated for the SEM based on chi-square distribution.

$$95\%\ CI\ for\ SEM = \frac{SSE}{X^2 a,dfe}\ ;\ \frac{SSE}{X^2{}_{1-.025},dfe}$$

The SSE is the sum of squares error in a ANOVA table. The 95% CI establishes a range of values within which a subjects' true SCE value is estimated to fall (25,67,71,78).

CHAPTER IV

RESULTS

The study population was comprised of 56 (31 females, 25 males) active duty United States Air Force (USAF) members performing their annual submaximal cycle ergometry (SCE) aerobic fitness assessment. The subjects were selected as a sample of convenience from squadrons performing their annual test during the data collection period. All subjects performed both tests during the same period of the day to eliminate potential circadian variability. Two subjects were excluded from the study because they had ingested caffeine within one hour of the assessment. Three subjects were excluded because they had participated in vigorous physical activity the day of their assessment. Five subjects were excluded because they had invalid tests. Descriptive statistics for males are summarized in Table 1 and for females in Table 2. The tables display the age, VO_{2max} values for both tests, and the absolute difference between the tests (71). Raw data is provided in Appendix J.

Table 1. Descriptive Statistics for Male Subjects (N = 25)

Variables	Mean	Standard Deviation
Age (yrs)	31.12	7.32
VO2max (ml/kg/min) Test 1	37.68	9.82
VO2max (ml/kg/min) Test 2	38.24	9.27
VO2max (ml/kg/min) Abs Diff	1.76	1.13

Table 2. Descriptive Statistics for Female Subjects (N = 31)

Variables	Mean	Standard Deviation
Age (yrs)	30.97	6.02
VO2max (ml/kg/min) Test1	28.26	4.34
VO2max (ml/kg/min) Test2	30	5.01
VO2max (ml/kg/min) Abs Diff	2.77	2.71

A repeated measures analysis of variance (ANOVA) was calculated by gender to provide the mean square error term to calculate the intraclass correlation coefficient (ICC) and standard error of the measurement (SEM). The ANOVA data is displayed in Table 3 for males and Table 4 for females (71).

Table 3. Results of the Repeated Measures ANOVA for Males

Source	Degrees of Freedom	Sum of Squares	Mean Square
Subjects	24	4333.92	180.58 (BMS)
Time	1	3.92	3.92 (RMS)
Subjects (time)	24	50.08	2.09 (EMS)

Table 4. Results of the Repeated Measures ANOVA for Females

Source	Degrees of Freedom	Sum of Squares	Mean Square
Subjects	30	1134.97	37.83 (BMS)
Time	1	47.03	47.03 (RMS)
Subjects (time)	30	182.97	6.1 (EMS)

<u>Note.</u> BMS = between-subjects mean square; RMS = between-raters mean square; EMS = error mean square.

Calculation of ICC (2,1):

$$\frac{BMS - EMS}{BMS + (k-1)EMS + \frac{k(RMS - EMS}{n}}$$

Calculation of the ICC (2,1) for males:

$$\frac{180.58 - 2.09}{180.58 + (2-1)\ 2.09 + \frac{2(3.92 - 180.58)}{25}}$$

ICC (2,1) for males = .91

Calculation of the ICC (2,1) for females:

$$\frac{37.83 - 6.10}{37.83 + (2-1)\,6.10 + \dfrac{2(47.03 - 37.83)}{31}}$$

ICC (2,1) for females = .71

Calculation of the SEM was accomplished by determining the square root of the mean square of the error (EMS) and expressed in the same units as the original measurement. The EMS for males was 2.09 and the EMS for females was 6.10.

SEM for males = 1.45 ml/kg/min

SEM for females = 2.47 ml/kg/min

Female subjects displayed greater within subject variability and a larger error than males.

Calculation of 95% Confidence Interval (CI) for SEM: $\frac{SSE}{X^2 a, dfe}$; $\frac{SSE}{X^2 1\text{-}.025, dfe}$

Calculation of 95% CI for males (SSE = 50.08): $\frac{50.08}{12.401}$; $\frac{50.08}{39.364}$

95% CI = 1.13 ; 2.01

Calculation of 95% CI for females (SSE = 182.97): $\frac{182.97}{16.791}$; $\frac{182.97}{46.979}$

95% CI = 1.97 ; 3.30

CHAPTER V

DISCUSSION

Comparisons to Previous Studies

There is no published research assessing the test-retest reliability of the United States Air Force (USAF) submaximal cycle ergometry (SCE) aerobic fitness test in male subjects. Hartung, et al., used 37 non-USAF, female subjects (19-47 yr) and determined the test-retest reliability of the USAF SCE to be r = 0.92 (39). This is the only published data determining the test-retest reliability of the USAF SCE test. Hartung, et al., provides anecdotal information that a skilled administrator using the USAF prototype interactive computer program would yield a higher test-retest reliability (39,40). Pollock, et al.(65), stated that repeat testing of the USAF SCE test showed it to be highly reliable, but gave no reliability statistics. They reported the mean and standard deviation in ml/kg/min for two consecutive tests. For males, test 1 was 48.2 +/- 15.1 and test 2 was 48.6 +/- 16.0. For females, test 1 was 37.1 +/- 12.5 and test 2 was 38.0 +/- 12.7 (65). The vast majority of research performed on the USAF SCE test is dedicated to determine the validity of the test versus maximal testing.

The USAF SCE test is a modification of the Astrand-Rhyming (A-R) SCE test (39,40,88). Two authors have reported the inter-test correlation to assess the test-retest reliability of the A-R test. Borg and Dahlstrom used 78 male subjects (20yr) and determined the test-retest reliability to be r = 0.95 (13). Williams used 31 female subjects and determined the test-retest reliability to be r = 0.64 from two trials in one day, r = 0.80 from three trials in three days, and r = 0.90 from six trials in six days (87).

Findings of This Study

The primary reason for the undertaking of this study was the limited amount of test-retest reliability research on the USAF SCE test. The most prominent finding was the moderate intraclass correlation coefficient (ICC) for females of ICC = 0.71. This study's moderate reliability coefficient indicates a relative lack of variability between subjects. This compares to the high reliability coefficient of r = 0.92 reported by Hartung (39). The lack of between subject variability can limit the use of ICC as a measure of reliability. The standard error of the measurement (SEM) for females was 2.47 ml/kg/min. The 95% confidence interval (CI) for the SEM for females was from 1.97 ml/kg/min to 3.30 ml/kg/min. The between-test SCE score varies between 1.97 ml/kg/min and 3.30 ml/kg/min of the observed score. In the Hartung study, great effort was used to recruit a more heterogeneous sample. The reported reliability of r = 0.64 on consecutive tests in the Williams study of the A-R protocol is closer to this study's findings. She used a homogeneous sample of 37 females in her study (87).

The USAF SCE test was highly reliable for males. The calculated ICC of 0.91 indicates a stable and precise measure of the USAF SCE test and shows that the test differentiates between subjects. The SEM for males was 1.45 ml/kg/min. The 95% CI for the SEM for males was from 1.13 ml/kg/min to 2.01 ml/kg/min. The between-test SCE score varies between 1.13 ml/kg/min and 2.01 ml/kg/min of the observed score. There are no comparable USAF SCE studies. However, the reported USAF SCE test-retest reliability of this study is very similar to the high reliability of r = 0.95 reported by Borg and Dahlstrom for the A-R protocol (13).

Limitations of This Study

The investigators' strict use of the USAF standardized protocol effectively eliminated methodological error and rater bias. The lack of between subject variability in the females is indicative of a homogenous sample. This may be attributed to the fact that all female subjects were sampled from support squadrons with relatively sedentary jobs. The lifestyle habits of the female subjects was not evaluated as a potential source of error. A more stratified female sample with a variety of occupational backgrounds may have improved reliability. Sample size for this study was 56 (31 females, 25 males). A larger sample size by gender and partitioned by age groups would increase the inference potential of this study.

Problems With USAF SCE Testing

A review of all tests performed in the USAF SCE testing facility was accomplished by the investigator during the two week data collection period of this study. A total of 284 tests, including the 56 reported in this study, were performed during the data collection period. Forty-five (16%) of the tests were considered invalid. Fifty-two (18%) represented a failure to meet standards on an initial test. This means that 32% of those tested will have at least one re-test. The USAF tests, at a minimum, approximately 290,000 personnel annually. A 32% (92,800) re-test rate throughout the Air Force could make administration of the SCE test labor intensive and costly. Cost effectiveness and administration simplicity were two of the primary reasons for changing the annual fitness testing process to SCE.

The USAF has established minimum fitness standards (Appendix I), in terms of estimated VO_{2max}, for each gender and grouped by age. Normative VO_{2max} values used by the Air Force is adapted from Cooper clinic norms (1). Cooper clinic norms were

collected from approximately 40,000 individuals (66). The USAF values range from 27 ml/kg/min to 22 ml/kg/min for females and 35 ml/kg/min to 27 ml/kg/min for males (1). As age increases the minimum standard decreases. When compared to the Cooper clinic norms, the USAF fitness standards ranked in the 10-15th percentile. The YMCA has established norms based on 22,000 tests. When compared to these norms, the USAF standards ranked in the poor category (15-25th percentile) (66). The potential 18% initial failure rate is plausible until viewed in terms of these low fitness standards.

The USAF SCE re-test criteria dictates that a second assessment be performed not less than 24 hours and not more than 7 days after the initial assessment. Of the 284 studies I reviewed, 15 (30%) of the 52 subjects who failed to meet standards did not adhere to the re-test criteria for the second assessment. The purpose of a re-test within 7 days is to avoid a potential change in the individual's aerobic fitness level and for administrative simplicity. Failure to adhere to the established criteria reduces the reliability of the USAF SCE test.

The largest potential problem with the USAF SCE testing program is the measurement error. In this study, the SEM was 2.47 ml/kg/min for females and 1.45 ml/kg/min for males. A myriad of confounding variables contribute to measurement error in submaximal testing. The A-R protocol is purported to have a 10-20% error potential (90). The USAF SCE has a measurement error ranging from 2.2-8.1 ml/kg/min for males and 2.2-2.3 ml/kg/min for females (39,40,65,88). For USAF personnel to "pass" their annual fitness assessment, they have to meet or exceed the established criteria. Measurement error can cause a fit person to fail. For example, a 25 yr. female has to achieve a VO_{2max} value of 27 ml/kg/min to meet standards. Based on this study, her observed score will vary between 1.97 ml/kg/min and 3.30 ml/kg/min. She may score a 25

ml/kg/min and fail to meet standards even though her retest VO_{2max} could be as high as 28 ml/kg/min. Failure to meet standards on repeat testing can lead to administrative disciplinary measures such as a mandatory fitness program, and a freeze placed on assignments or promotions. In male personnel the potential to fail to meet standards due to measurement error is less although not absent. The low fitness standards should eliminate this potential problem, however, the lack of a range of acceptable values may have detrimental effects on an individual's career.

Recommendations for Future Studies

The USAF SCE test has been in use for almost six years. However, only four published studies report the validity and reliability of the program. The research potential is vast among Air Force personnel considering the fact that more than 300,000 tests are performed annually. The paucity of research in this area is not parallel to the amount of time, personnel, and resource that has been dedicated to the USAF SCE program. The primary focus should be on investigating test-retest reliability, reducing the number of invalid tests, establishing an acceptable range of values around the fitness standards criteria, and determining the effects of deviation from the established re-test criteria.

A major concern of any researcher performing a study with repeated measures is a learning or trial effect. Learning can occur following only one bout of an exercise test. This learning effect can improve mechanical efficiency and skew test results. Researchers usually use a pilot study or a familiarization period to eliminate a learning effect. A variety of authors (7,13,26,38,39,49,50,65,66,87,88) have mentioned that a progressive increase in estimated VO_{2max} with repeat SCE testing represents a learning effect. The effect of learning on submaximal estimation of VO_{2max} has not been studied.

CHAPTER VI

SUMMARY

The purpose of this study was to determine the test-retest reliability of the United States Air Force (USAF) submaximal cycle ergometry (SCE) test for both male and female populations. The research question asked, "Does the USAF SCE test provide a stable measurement of VO_{2max} with repeat testing?" The answer to the research question was yes for males and females. For males, the intraclass correlation coefficient (ICC) was 0.91 and the standard error of the measurement (SEM) was 1.45 ml/kg/min. The USAF SCE test for males was shown to be highly reliable. For females, the ICC was 0.71 with a SEM of 2.47 ml/kg/min. The USAF SCE test for females was shown to be only moderately reliable and should be viewed with caution.

Estimation of VO_{2max} from SCE work and heart rate is prone to errors. These errors should be considered when implementing this form of testing for either fitness or performance evaluations. Astrand reported, in a commentary, that submaximal testing is a good simple screening test that is a wonderful tool to stimulate regular aerobic exercise, however, should not be used for decision making. The USAF does an admirable job administering SCE test, considering the shear volume of tests performed.

The purpose of the study was accomplished and the research question was answered. The ultimate goal of any researcher is to contribute to the body of literature. It is the opinion of this author that this goal has been accomplished.

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UNIVERSITY OF OKLAHOMA HEALTH SCIENCES CENTER
and the
72nd Medical Group, Cycle Ergometry Test Center, Tinker Air Force Base

Individual's Consent for Voluntary Participation in a Research Project

I,______________________________, voluntarily agree to participate in this study entitled: The Re-test Reliability of the United States Air Force's Submaximal Bicycle Ergometry Aerobic Fitness Test. This study will be conducted by Mark Anderson, Ph.D., PT, ATC and Captain Frank A. Glenn, PT and sponsored by the Tinker Air Force Base Cycle Ergometry Test Center.

1. Purpose: I understand that the purpose of this study is to determine the reliability of the United States Air Force submaximal bicycle ergometry aerobic fitness test by comparing an individuals VO2max values on successive tests. I further understand that no aspect of this study will affect the outcome of my annual test.

2. Description of Study: I understand that if I agree to participate in this study, that the normal and standardized Air Force annual cycle ergometry fitness assessment protocol and procedures of which I am accustomed will be used. I understand the test is a 6-9 minute bicycle test at a relatively easy (submaximal workload) resistance to measure my physical fitness level.

3. Costs: I understand that I will not receive compensation or bills for participating in this study.

4. Risks: I understand that there will be no risk to me as a participant of this study.

5. Benefits: I understand that there will be no benefits to me as a participant of this study.

6. Subjects Assurances: I understand that my participation in this study is voluntary. I understand that I may revoke my consent and withdraw at any time if I so desire. I will not be penalized in anyway for refusing to participate. I have not given up any of my legal rights or released any individual or institution from liability for negligence.

I understand that records of this study will be kept confidential, and that I will not be identified by name in any report or publication. Records of my participation in this study may only be disclosed in accordance with federal law, including the Federal Privacy Act (1974), 5 U.S.C 552a, and its implementing regulation.

Test-Retest Reliability of the USAF Submaximal Bicycle Ergometry Aerobic Fitness Test

I understand that if I have questions about this study, or need to report any adverse effects from the research procedures, I will contact Dr. Mark Anderson at (405) 271-2131 ext.130 or Captain Frank Glenn at (405) 773-7286. Lastly, if I have questions about my rights as a research subject, I may contact the Director of Research Administration, in the Oklahoma University Health Sciences Center, at (405) 271-2090.

I have read this informed consent document. I agree to participate in this research freely and voluntarily under the conditions described in this document and understand that I will receive a copy of this signed consent form.

Research Subject:______________________________ Date:_______________

Witness:______________________________________ Date:_______________

Investigator:__________________________________ Date:_______________

FITNESS SCREENING QUESTIONNAIRE

It is mandatory that all personnel are screened prior to being scheduled for fitness assessment.

1. Are you currently on a medical profile exempting you from fitness activities or fitness assessment?

2. Has a doctor or health care provider ever said you have heart disease or heart trouble?

3. Do you feel you may have heart disease or heart trouble, or have symptoms of heart disease or heart trouble, such as:

   a. Do you suffer from pains in your chest, especially with physical activity?

   b. Do you often feel faint or have spells of severe dizziness?

4. Are you taking medication for high blood pressure? Has high blood pressure medication been prescribed for you that you are not taking at the present time?

5. Has a doctor or health care provider ever told you that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise?

6. Are you pregnant or think you may be pregnant?

7. Are you taking any medication, either from a health care provider or over the counter, on a regular basis which you believe may affect your heart rate or your ability to exercise?

If all the answers to this questionnaire are "NO", please sign and date. This questionnaire will be kept in your fitness file by the UFPM.

Name: ______________________________ Date: __________

If ANY of your answers to these questions is "YES" please notify the Unit Fitness Program Manager (UFPM), or the Fitness Assessment Monitor (FAM). NOTE: You do not need to specify which question(s) (is) (are) affirmative. The UFPM will ensure that a medical evaluation is performed to determine if you should undergo fitness assessment.(1)

AEROBIC FITNESS ASSESSMENT PREPARATION HANDOUT

Your level of cardiorespiratory (aerobic) fitness will be evaluated by a submaximal cycle ergometry method. In this assessment, your cardiovascular response to a precise amount of moderate exercise will provide the basis for estimating your aerobic capacity.

The assessment involves 8 to 12 minutes of moderate exercise on a precision cycle ergometer. The workload will be adjusted according to your physical capability. Before and during this exercise, your heart rate will be carefully recorded and your fitness level will be calculated from the combination of heart rate and workload. To achieve the best score possible, you are encouraged to arrive at your appointed time after observing the following preparatory recommendations. Failure to follow these recommendations may result in an under estimation of your true fitness level. If you fail to follow these recommendations, the assessment will still be performed as scheduled. (1)

- Maintain a calm state of mind and body. Do not "pump yourself up" as in preparation for a game or athletic trial. Avoid any stimulation that could raise your heart rate. Perform the assessment with as little effort as possible. Avoid excessive emotions, especially anxiety or worry.

- Maintain or moderate your normal lifestyle up to one (1) hour prior to testing. At that time, limit all caffeine, tobacco, and food intake. Maintain adequate fluid intake.

- Do not change your normal habits to such an extent that you experience withdrawal symptoms from caffeine or tobacco. However, do not overindulge in caffeine, tobacco, alcohol, or heavy or spicy meals.

- Avoid alcohol and heavy physical activity the night before and the day of your assessment.

- Get a good night's sleep prior to the assessment.

- Wear loose fitting trousers or shorts and comfortable shoes acceptable for this cycling activity. Boots are not allowed; shoes must be worn

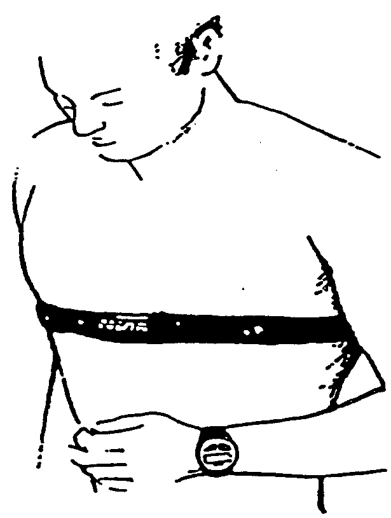
- Wear clothing that will allow a heart rate monitor to be attached to the skin on your lower chest. (Female: Metal underwire bras interfere with the heart rate monitor and will not be worn.) Evaluations will be as private as possible. The fitness assessment monitor may be male or female.

HEART RATE MONITOR PREPARATION

Demonstrate proper application of the chest strap and transmitter If the member is a:

Female: Explain to the member that she needs to secure the elastic strap on the chest transmitter so that it fits snugly below the bottom of the bra. Allow her to attach the transmitter in privacy. (Metal underwire bras may not be worn during the assessment because it will interfere with the heart rate signal. If the female cannot change into an acceptable bra, you need to inform the UFPM to reschedule her assessment.)

Male: Explain to the member that he must raise his shirt to the bottom of his pectoral muscles and must attach the chest strap and transmitter snugly, directly under the pectoral muscles.. Allow him to attach the transmitter in private if he wishes.



Place the wristwatch receiver on the member's wrist or on the cycle handlebars. Adjust the wristwatch receiver until you receive a consistent heart rate signal. If you are not receiving a consistent heart rate, move the wristwatch receiver closer to the transmitter, re-wet the electrodes on the strap, or put a fresh battery in the transmitter. (Some transmitter batteries are not replaceable, and must be exchanged by the company. In case you attempt to use one of these receivers, replace it with another and insure the receiver is returned to supply for shipment to the company.) Be sure to keep the wristwatch receiver within three feet of the transmitter to assure a good signal.(1)

CALIBRATION OF CYCLE ERGOMETER:

1) You must ensure that the cycle ergometer and weight and measurement scales are calibrated initially by base Precision Measurement Equipment Laboratory (PMEL), or comparable entity, at least annually. This calibration is a more in-depth calibration, similar to that specified in the owners manual that came with the cycle.

2) You must perform a routine calibration on the cycles daily. This is initiated by relieving the belt tension. Relief of the belt tension is achieved by turning the load adjustment wheel counter clock wise until the pendulum weight hangs freely. The tension belt should be loose at this point. Align the index line on the pendulum weight with the zero ("0") mark in the meter board. (see Fig. 2) If not aligned, loosen the wing nut that locks the adjusting screw and the meter board until the "0" on the meter board is aligned with the red mark in the pendulum weight. After aligning, tighten the wing nut. Ensure that the meter board did not move. Check alignment and repeat the procedure if necessary.

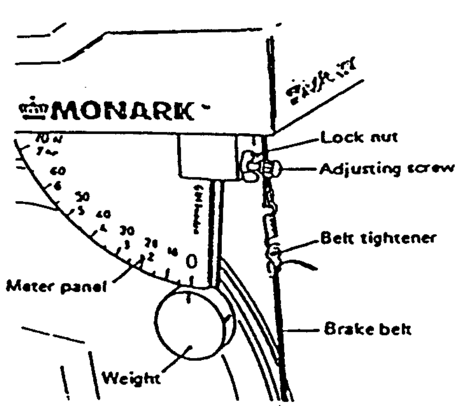


Figure 2

3) You must calibrate the cycle before the beginning of each evaluation. This is to assure calibration was not effected by the previous assessment. You must explain to the members that all adjustments will be made by you. It is imperative that the member not touch the adjustment wheel at any time during the evaluation. (see Fig. 3) If the member adjusts the wheel during the evaluation the workload resistance will be altered; therefore, invalidating the assessment results.(1)

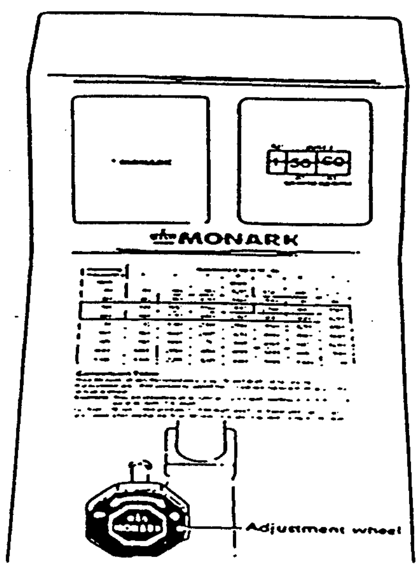


Figure 3

CYCLE PREPARATION

Adjust the seat height. To accomplish this action, begin by setting the seat at a level even with the member's hip. This is a good approximation and will make additional adjustments easier. Then instruct the member to sit on the cycle without using the frame or pedals as a step. Have the member place his/her heel in the middle of the cycle pedal, so that the leg is in the six o'clock position. (see Fig. 6) (Have the member dismount the cycle for any seat adjustments) Unscrew the saddle post bolt, and adjust the seat height so the leg is straight when it is in this position. (see Fig. 6) After the adjustment is correct, have the member remount the cycle and move the foot back, so the ball of the foot is in the middle of the pedal. This technique will assure both you and the member that the seat height is in the most advantageous position. Be sure the pedal straps are removed, if the cycle has them. (The member may feel this seat adjustment is not comfortable, however, it is important for it to remain at this setting. [Many people are used to riding bikes with improperly adjusted seats. A seat that is adjusted too high may cause over extension and a seat that is adjusted too low may cause cramping and premature fatigue, which may cause an unacceptable assessment.]).(1)

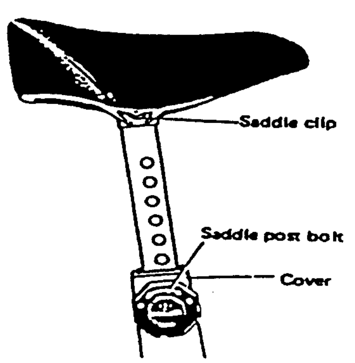


Figure 5

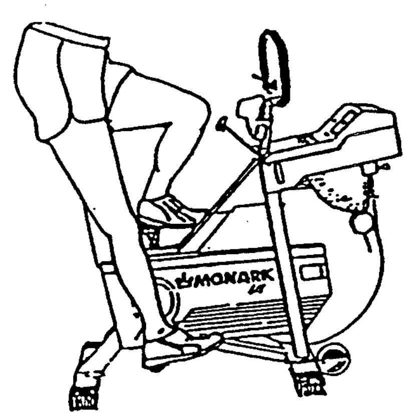


Figure 6

	Weight									
	<54.88 kg (<121 lbs.)		<63.95 kg (<141 lbs.)		<73.02 kg (<161 lbs.)		<82.09 kg (<181 lbs.)		<226.76 kg (<500 lbs.)	
Exercise History	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
Age										
17 - 35	1.0	1.0	1.5	1.0	1.5	1.0	2.0	1.5	2.0	2.0
36 - 50	1.0	1.0	1.5	1.0	1.5	1.0	2.0	1.5	2.0	1.5
51 - 62	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.0	1.5	1.0
63 - 70	1.0	0.5	1.0	0.5	1.0	1.0	1.5	1.0	1.5	1.0

Initial workload cycle settings for females in kp.

	Weight									
	<59.41 kg (<131 lbs.)		<68.48 kg (<151 lbs.)		<82.09 kg (<181 lbs.)		<100.23 kg (<221 lbs.)		<226.76 kg (<500 lbs.)	
Exercise History	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
Age										
17 - 35	1.5	1.0	2.0	1.5	2.0	2.0	2.5	2.0	2.5	2.5
36 - 50	1.5	1.0	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.0
51 - 62	1.5	1.0	1.5	1.0	2.0	1.5	2.0	1.5	2.0	1.5
63 - 70	1.0	1.0	1.5	1.0	1.5	1.0	1.5	1.5	1.5	1.5

Initial workload cycle settings for males in kp.

	Workload Progression											
	+1 kp			**+0.5 kp**			**0.0 kp**			**Terminate Assessment**		
Minute	**3**	**4**	**5**	**3**	**4**	**5**	**3**	**4**	**5**	**3**	**4**	**5**
Age												
17 - 30	<110	<110	<115	110-119	110-119	115-128	120-173	120-173	129-173	invalid if >85% of max. heart rate		
31 - 40	<105	<105	<110	105-114	105-114	110-126	115-161	115-161	127-161			
41 - 50	<100	<100	<105	100-109	100-109	105-122	110-152	110-152	123-152			
51 - 60	<100	<100	<105	100-109	100-109	105-120	110-144	110-144	121-144			
61 - 70	<90	<90	<95	90-104	90-104	95-105	105-135	105-135	106-135			

Progression workload cycle changes*.

* Note: Heart rates used to determine workload progression are taken at the end of the minute. For example, minute three of the test is performed at the initial workload, with the heart rate at the end of minute three (2:55) determining the workload progression for minute four using "Minute 3" workload progression column. (1)

USAF FITNESS PROGRAM
Individual Assessment Report
[date]

[Rank] [Name], [SSN], your score of [nn] meets or exceeds The Air Force minimum fitness standard of [nn].

Congratulations! Your score indicates the need for you to maintain your current conditioning program or you will lose the health and performance benefits you gained by reaching this level of fitness.

Additional health and performance benefits can be gained by increasing your aerobic fitness score. This can be accomplished by increasing your activity's frequency, intensity, or time (duration).

Cross training, or varying the type of exercise you perform, can help prevent injuries and loss of motivation (boredom or burnout).

Strength, endurance, and flexibility are additional aspects of overall health and fitness. You are encouraged to incorporate them into your exercise regimen.

Your base fitness expert can help you tailor an exercise program that is right for you and your fitness goals. (1)

Age: [nn] Gender: [n] Height: [nn.n] inches Weight: [nnn.n] lb.
Final Heart Rate: [nnn] bpm Final Workload: [nn.n] kp

AIR FORCE AEROBIC FITNESS STANDARDS

MEASURED IN MAXIMAL OXYGEN UPTAKE (V02) AS PREDICTED BY SUBMAXIMAL CYCLE ERGOMETRY

AGE (Yr)	FEMALES	MALES
< 24	27	35
25-29	27	34
30-34	27	32
35-39	26	31
40-44	26	30
45-49	25	29
50-54	24	28
55-59	22	27

(1)

OBS	SUBJ	AGE	GEN	TIME	SCORE
1	1	36	1	1	25
2	1	36	1	2	22
3	2	34	1	1	23
4	2	34	1	2	30
5	3	42	1	1	24
6	3	42	1	2	25
7	4	33	1	1	26
8	4	33	1	2	28
9	5	28	1	1	24
10	5	28	1	2	37
11	6	37	1	1	24
12	6	37	1	2	22
13	7	34	1	1	26
14	7	34	1	2	29
15	8	28	1	1	24
16	8	28	1	2	25
17	9	26	1	1	25
18	9	26	1	2	33
19	10	21	1	1	23
20	10	21	1	2	27
21	11	24	1	1	29
22	11	24	1	2	31
23	12	28	1	1	32
24	12	28	1	2	37
25	13	32	1	1	36
26	13	32	1	2	37
27	14	35	1	1	24
28	14	35	1	2	25
29	15	33	1	1	24
30	15	33	1	2	22
31	16	37	1	1	29
32	16	37	1	2	33
33	17	22	1	1	36
34	17	22	1	2	37
35	18	25	1	1	32
36	18	25	1	2	36
37	19	26	1	1	33
38	19	26	1	2	33
39	20	34	1	1	31
40	20	34	1	2	34
41	21	37	1	1	24
42	21	37	1	2	24
43	22	23	1	1	25
44	22	23	1	2	24
45	23	23	1	1	33

OBS	SUBJ	AGE	GEN	TIME	SCORE
46	23	23	1	2	33
47	24	33	1	1	26
48	24	33	1	2	27
49	25	26	1	1	35
50	25	26	1	2	36
51	26	35	1	1	26
52	26	35	1	2	31
53	27	33	1	1	29
54	27	33	1	2	30
55	28	32	1	1	34
56	28	32	1	2	36
57	29	22	1	1	35
58	29	22	1	2	33
59	30	40	1	1	29
60	30	40	1	2	27
61	31	41	1	1	30
62	31	41	1	2	26
63	32	32	0	1	26
64	32	32	0	2	29
65	33	23	0	1	49
66	33	23	0	2	51
67	34	28	0	1	28
68	34	28	0	2	30
69	35	26	0	1	28
70	35	26	0	2	32
71	36	28	0	1	29
72	36	28	0	2	31
73	37	20	0	1	62
74	37	20	0	2	61
75	38	24	0	1	45
76	38	24	0	2	44
77	39	22	0	1	35
78	39	22	0	2	33
79	40	28	0	1	30
80	40	28	0	2	31
81	41	22	0	1	50
82	41	22	0	2	50
83	42	41	0	1	36
84	42	41	0	2	36
85	43	30	0	1	39
86	43	30	0	2	38
87	44	31	0	1	42
88	44	31	0	2	41
89	45	47	0	1	28
90	45	47	0	2	28

OBS	SUBJ	AGE	GEN	TIME	SCORE
91	46	45	0	1	28
92	46	45	0	2	24
93	47	32	0	1	24
94	47	32	0	2	26
95	48	31	0	1	32
96	48	31	0	2	35
97	49	36	0	1	38
98	49	36	0	2	39
99	50	31	0	1	43
100	50	31	0	2	40
101	51	39	0	1	36
102	51	39	0	2	39
103	52	41	0	1	35
104	52	41	0	2	37
105	53	37	0	1	33
106	53	37	0	2	34
107	54	24	0	1	42
108	54	24	0	2	44
109	55	28	0	1	50
110	55	28	0	2	51
111	56	32	0	1	54
112	56	32	0	2	52

Author: Frank A. Glenn, Captain, USAF, BSC
Title: The Test-Retest Reliability of the United States Air Forces Submaximal Bicycle Ergometry Aerobic Fitness Test
Year: 1998
Number of Pages: 66
Degree: Master of Science in Physical Therapy
Institution: University of Oklahoma - Health Sciences Center

Since 1992, the United States Air Force (USAF) has employed submaximal cycle ergometry to predict VO_{2max} and determine the level of aerobic fitness in its members. The purpose of this study was to determine the test-retest reliability of the USAF SCE test for both male and female populations. Fifty-six Air Force subjects (25 males and 31 females) were selected from a sample of convenience of members performing their annual cycle ergometry test. Each member performed two assessments within the retest criteria of not less than 24 hours and not greater than 7 days after the initial test. Reliability was determined by intraclass correlation coefficient (ICC), standard error of the measurement (SEM), and a 95% confidence interval (CI) for the SEM. For males, the ICC = 0.91 and the SEM = 1.45 ml/kg/min. The 95% CI determined the between-test SCE score varies between 1.13 and 2.01 ml/kg/min of the observed score. For females, the ICC = 0.71 and the SEM = 2.47 ml/kg/min. The 95% CI determined the between-test SCE score varies between 1.97 and 3.30 ml/kg/min of the observed score. The USAF SCE test was shown to be highly reliable for males and moderately reliable for females.